EH710682356

NASA
National Aeronautics and Space Administration

PATENT

Docket No.: **LAR 15348-2**

Box Patent Application

Commissioner of Patents and Trademarks

Washington, D.C. 20231

CERTIFICATION UNDER 37 CFR 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date 24 Jan 1997 in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EH710682356 addressed to the: Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Kimberly A Chasteen
KIMBERLY A. CHASTEEN

NOTE: Each paper or fee referred to as enclosed herein has the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 CFR 1.10(b).

NEW APPLICATION TRANSMITTAL UNDER 35 USC 111

Transmitted herewith for filing is the patent application of

Inventor(s):
RICHARD F. HELLBAUM ET AL.

WARNING: Patent must be applied for in the name(s) of all of the actual inventor(s). 37 CFR 1.41(a) and 1.53(b).

For (title): **THIN-LAYER COMPOSITE-UNIMORPH FERROELECTRIC DRIVER AND SENSOR**

1. **Type of Application**

This new application is for a(n) (check one applicable item below):

_	Original
_	Design
_	Plant

WARNING: Do not use this transmittal for a completion in the U.S. of an International Application under 35 U S. C. 371(c)(4) unless the International Application is being filed as a divisional,continuation or continuation-in-part application.

NOTE: If one of the following 3 items apply then complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF A PRIOR U.S. APPLICATION CLAIMED.

_	Divisional
✓	Continuation under 35 USC 111
_	Continuation-in-part (CIP)

2. **Benefit of Prior U.S. Application(s) (35 USC 120)**

NOTE: If the new application being transmitted is a divisional, continuation or a continuation-in-part of a parent case, or where the parent case is an International Application which designated the U.S., then check the following item and complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

_ The new application being transmitted claims the benefit of prior U.S. application(s) and enclosed are ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

✓ The new application being transmitted claims the benefit of prior U.S. application(s). This information has been incorporated into the specification being filed herwith.

3. **Papers Enclosed Which Are Required For Filing Date Under 37 CFR 1.53(b) (Regular) or 37 CFR 1.153 (Design) Application**

9 Pages of specification
2 Pages of claims
1 Pages of Abstract
8 Sheets of drawing

✓ formal

_ informal

WARNING: DO NOT submit original drawings. A high quality copy of the drawings should be supplied when filing a patent application. The drawings that are submitted to the Office must be on strong, white, smooth, and non-shiny paper and meet the standards according to § 1.84. If corrections to the drawings are necessary, they should be made to the original drawing and a high-quality copy of the corrected original drawing then submitted to the Office. Only one copy is requlied or desired. Comments on proposed new 37 CFR 1.84. Notice of March 9, 1988 (1990 O.G. 57-62).

NOTE: "Identifying indicia such as the serial number, group and unit, title of the invention, attorney's docket number, inventor's name, number of sheets. etc., not to exceed 2-3/4, inches (7.0 cm.) in width may be placed in a centered location between the side edges within three fourths inch (19.1 mm.) of the top edge. Either this marking technique on the front of the drawing or the placement, although not preferred, of this information and the title of the invention on the back of the drawings is acceptable. " Proposed 37 CFR 1.84(1). Notice of March 9, 1988 (1090 O.G. 57-62).

4. **Additional papers enclosed**

_ Preliminary Amendment
_ information Disclosure Statement
_ Form PTO-1449
_ Citations
_ Declaration of Biological Deposit
_ Submission of "Sequence Listing," computer readable copy and/or amendment pertaining thereto for biotechnology invention containing nucleotide and/or amino acid sequence.
_ Authorization of Attorney(s) to Accept and Follow Instructions from Representative
_ Special Comments
_ Other

5. **Declaration or oath**

✓ Enclosed and/or ✓ executed by inventor(s) (check all applicable boxes)

_ UNEXECUTED - Inventors not available for signature at time of filing. A properly executed declaration will be forwarded upon receipt of the "Notice to File Missing Parts"

_ legal representative of inventor(s). 37 CFR 1.42 or 1.43

_ joint inventor or person showing a proprietary interest on behalf of inventor who refused to sign or cannot be reached.

_ this is the petition required by 37 CFR 1.47 and the statement required by 37 CFR 1.47 is also attached. See item 13 below for fee.

_ Not Enclosed.

WARNING: Where the filing is a completion in the U.S. of an international Application but where a declaration is not available or where the completion of the U.S. application contains subject matter in addition to the International Application the application may be treated as a continuation or continuation-in-part, as the case may be, utilizing ADDED PAGE FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION CLAIMED.

_ Application is made by a person authorized under 37 CFR 1.41(c) on behalf of all the above named inventor(s). The declaration or oath, along with the surcharge required by 37 CFR 1.16(e) can be filed subsequently.

NOTE: It is important that all the correct inventor(s) are named for filing under 37 CFR 1.41(c) and 1.53(b).

_ Showing that the filing is authorized. (Not required unless called Into question. 37 CFR 1.41(d).

6. Inventorship Statement

WARNING: If the named Inventors are each not the inventors of all the claims an explanation including the ownership of the various claims at the time the last claimed Invention was made, should be submitted.

The inventorship for all the claims in this application are:

✓ The same

or

_ Are not the same. An explanation, including the ownership of the variouS claims at the time the last claimed invention was made,

_ is submitted.

_ will be submitted.

7. Language

NOTE: An application including a signed oath or declaration may be filed in a language other than English. A verified English translation of the non-English language application and the processing fee of $130.00 required by 37 CFR 1.17(k) is required to be flied with the application or within such time as may be set by the Office. 37 CFR 1.52(d).

NOTE: A non-English oath or declaration in the form provided or approved by the PTO need not be translated. 37 CFR 1.69(b)

✓ English

_ non-English

_ the attached translation is a verified translation. 37 CFR 1.52(d).

8. Assignment

✓ An assignment of the invention to the **Government of the United States as Represented by the Administrator of the National Aeronautics and Space Administration**

✓ is (are attached. A separate "ASSIGNMENT COVER LETTER ACCOMPANYING NEW PATENT APPLICATION" is also attached.

_ will follow.

NOTE: "If an assignment is submitted with a new application, send two separate letters-one for the application and one for the assignment." Notice of May 4. 1990 (1114 O.G. 77-78).

9. **Certified Copy**

Certified copy(ies) of application(s)

(country) (appln. no.) (filed)

(country) (appln. no.) (filed)

(country) (appln. no.) (filed)

from which priority is claimed

_ is (are) attached.
_ will follow.

NOTE: The foreign application forming the basis for the claim for priority must be referred to in the oath or declaration. 37 CFR 1.55(a) and 1.63.

NOTE: This item is for any foreign priority for which the application being filed directly relates. if any parent U.S. application or International Application from which this application claims benefit under 35 U.S.C. 120 is itself entitled to priority from a prior foreign application then complete item 18 on the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

10. **Fee Calculation (37 CFR 1.16)**

✓ **A.** Regular application

CLAIMS AS FILED

Number filed	Number Extra	Rate	Basic Fee - $770.00
Total Claims 8 (37 CFR 1.16(c))	20-20 = 0	0 X $22.00	$0.00
Independent Claims (37 CFR 1.16(b)) 1	3-3 = 1	0 X $80.00	$0.00
Multiple Dependent Claims, if any (37 CFR 1.16(d)) 0	= 0	X $260.00	$0.00

_ Amendment cancelling extra claims enclosed.

_ Amendment deleting multiple-dependencies enclosed.

_ Fee for extra claims is not being paid at this time.

NOTE: If the fees for extra claims are not paid on filing they must be paid or the claims cancelled by amendment, prior to the expiration of the time period set for response by the Patent and Trademark Office in any notice of fee deficiency. 37 CFR 1.16(d).

Filing Fee Calculation **$770.00**

_ **B.** Design application ($280.00--37 CFR 1.16(f))
Filing Fee Calculation $

_ **C.** Plant application ($460.00--37 CFR 1.16(g))

Filing fee calculation $

11. **Small Entity Statement(s)**

_ Verified Statement(s) that this is a filing by a small entity under 37 CFR 1.9 and 1.27 is (are) attached.

Filing Fee Calculation (50% of A, B or C above) $

NOTE: Any excess of the full fee paid will be refunded if a verified statement and a refund request are filed within 2 months of the date of timely payment of a full fee. 37 CFR 1.28(a).

12. **Request for International-Type Search (37 CFR 1.104(d)) (complete, if applicable)**

_ Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

13. **Fee Payment Being Made At This Time**

_ Not Enclosed

_ No filing fee is to be paid at this time. (This and the surcharge required by37 CFR 1.16(e) can be paid subsequently.)

✓ Enclosed

✓	basic filing fee	**$770.00**
✓	recording assignment ($40.00; 37 CFR 1.21(h))	**$40.00**
_	petition fee for filing by other than all the inventors or person on behalf of the inventor where inventor refused to sign or cannot be reached. ($130.00; 37 CFR 1.47 and 1.17(h))	$0.00
_	for processing an application with a specification in a non-English language. ($130.00; 37 CFR 1.52(d) and 1.17(k)	$0.00
_	processing and retention fee ($130.00; 37 CFR 1.53(d) and 1.21(l))	$0.00
_	fee for international-type search report ($35.00; 37 CFR 1.21(e)).	$0.00

NOTE: 37 CFR 1.21(l) establishes a fee for processing and retaining any application which is abandoned for failing to complete the application pursuant to 37 CFR 1.53(d) and this, as well as the changes to 37 CFR 1.53 and 1.78, indicate that in order to obtain the benefit of a prior U.S. application, either the basic filing fee must be paid or the processing and retention fee of § 1.21(l) must be paid within 1 year from notification under § 1.53(d).

Total fees enclosed **$810.00**

14. **Method of Payment of Fees**

_ Check in the amount of $

✓ Charge Account No. **14-0116** in the amount of $**810.00**. A duplicate of this transmittal is attached.

NOTE: Fees should be itemized in such a manner that it is clear for which purpose the fees are paid 37 CFR 1.22(b).

15. **Authorization to Charge Additional Fees**

WARNING: If no fees are to be paid on filing the following Items should not be completed.

WARNING: Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges. If extra claim charges are authorized.

✓ The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. **14-0116**

✓ 37 CFR 1.16(a), (f) or (g) (filing fees)
✓ 37 CFR 1.16(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 CFR 1.16(d)), it might be best not to authorize the PTO to charge additional claim fees, except possibly when dealing with amendments after final action.

✓ 37 CFR 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)
✓ 37 CFR 1.17 (application processing fees)

WARNING: While 37 CFR 1.17(a). (b), (c) and (d) deal with extensions of time under § 1.136(a) this authorization should be made only with the knowledge tnat: "Submission of the appropriate extension fee under 37 C.F.R. 1.136(a) is to no avail unless a request or petition for extension is filed." (Emphasis added). Notice of November 5, 1985 (1060 O.G. 27).

– 37 CFR 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 CFR 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the Issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 CFR 1.311(b).

NOTE: 37 CFR 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application. . . prior to paying, or at the time of paying,. . . issue fee." From the wording of 37 CFR 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification Is required if the change is to another small entity.

16. **Instructions As To Overpayment**

✓ credit Account No. **14-0116**

– refund

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Mail Stop 212
3 Langley Boulevard
Hampton, VA 23681-0001

Date : 24 Jan 1997

✓ **INCORPORATION BY REFERENCE OF ADDED PAGES**

Check the following item if the application in this transmittal claims the benefit of prior U.S. application(s) (including an international application entering the U.S. stage as a continuation, divisional or C-I-P application) and complete and attach the ADDED PAGES FOR NEW APPLIATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED

_ Plus added pages for new application transmittal where benefit of prior U.S. application(s) claimed

Number of pages added:

_ Plus added pages for papers referred to in Item 4 above

Number of pages added:

✓ Plus "Assignment cover letter accompanying new application"

Number of pages added: 3

_ **Statement Where No Further Pages Added**

(If no further pages form a part of this Transmittal then end this Transmittal with this page and check the following item)

_ This transmittal ends with this page.

THIN LAYER COMPOSITE UNIMORPH FERROELECTRIC DRIVER AND SENSOR

This application is a continuing application of commonly-owned patent application Serial No. 08/416,598, filed April 4, 1995.

Origin of the Invention

The invention described herein was made by employees of the United States Government and may be used by and for the Government for governmental purposes without the payment of any royalties thereon or therefor.

Background of the Invention

1. Technical Field of the Invention

The present invention relates generally to ferroelectric devices, and more particularly to ferroelectric devices providing large mechanical output displacements.

2. Discussion of the Related Art

Prior art methods include 'Rainbow' piezoelectric actuators and sensors, more conventional piezoelectric actuators and sensors, and electro-magnetic actuators.

Conventional piezoelectric actuators exhibit limited mechanical displacements. The output of conventional piezoelectric devices is limited by the material's basically low piezoelectric displacement constant. Thus conventional devices of reasonable thickness (i.e. on the order of a few

millimeters) offer only micrometer-sized mechanical output motion. 'Rainbow' actuators, 'Moonies', unimorphic, and bimorphic piezoelectric actuators exhibit greater mechanical output motion. However even the thinnest ceramic wafers, which exhibit the maximum observed output motion, provide a displacement limited to approximately 1 mm of motion in the z-direction for a device that is 3-4 cm long. Additionally ¼ mm thick ceramic devices are extremely brittle and fragile so that they are prone to breakage and require special handling. Previous methods of forming 'Rainbow' actuators include an additional chemical reduction process which releases lead vapors from the wafer into the atmosphere.

It is accordingly an object of the present invention to provide a ferroelectric actuator with improved mechanical displacement.

It is another object of the present invention to provide a ferroelectric actuator with improved durability.

It is another object of the present invention to provide a ferroelectric actuator with improved machinability.

It is another object of the present invention to provide a method for producing a ferroelectric actuator which is more environmentally safe than previous methods.

It is yet another object of the present invention to accomplish the foregoing objects in a simple manner.

Additional objects and advantages of the present invention are apparent from the drawings and specification which follow.

Summary of the Invention

According to the present invention, the foregoing and additional objects are obtained by providing a method for producing ferroelectric devices. First, a mold is selected for the device. A prestress layer is placed on the mold and a ferroelectric layer is placed on top of the prestress layer.

These layers are bonded together by heating and then cooling the assembled device. The prestress layer may be an adhesive and may include reinforcing material. The ferroelectric layer may be a piezoelectric material, a piezostrictive material or a composite. The ferroelectric layer includes surface electrodes which may be applied by including an electrode layer on either side of the ferroelectric layer prior to heating the assembly.

Brief Description of the Drawings

Fig. 1 is a perspective view of the preferred embodiment prior to bonding the layers;

Fig. 2 is a cross sectional view of the preferred embodiment after cooling of the layers;

Fig. 3 is a cross sectional view of an alternate embodiment of the present invention;

Fig. 4 is a cross sectional view of an alternate embodiment of the present invention;

Fig. 5 is a cross sectional view showing the manufacturing process of the present invention;

Fig. 6 is perspective view showing an alternate embodiment of the present invention;

Fig. 7 is a top view showing a plurality of prestressed wafers connected to form a larger wafer; and

Fig. 8 is a side view showing three of the prestressed wafers in a stacked configuration.

Detailed Description of the Preferred Embodiment

Figure 1 shows a piezoelectric device 10 according to the present invention prior to being processed. The device includes four layers, a piezoelectric layer 12, a prestressing layer 14 and two electrode layers 18a and 18b. The piezoelectric layer 12 can be made from a disk of piezoelectric material commercially available from Aura Ceramics (C3900 material) or Morgan Matrox. Alternatively, this layer can be made from piezoelectric material that was first ground to a fine powder and subsequently consolidated into a layer by compression bonding the powder with an adhesive such as a polyimide, as shown in "Tough, Soluble, Aromatic, Thermoplastic Copolyimides", Serial No. 08/359,752, filed December 16, 1994. Note that in the latter approach, the adhesive binder makes up a very small fraction, typically 5 percent by weight, of the finished piezoelectric layer 12. This latter approach is attractive since the required bonding operation can simply be performed simultaneously with other needed bonding operations discussed in the next paragraph. In addition to piezoelectric materials, other ferroelectric materials, including piezostrictive materials may be used to form this layer.

The prestressing layer 14 can be made of a mechanically strong adhesive such as a polyimide. Thermoplastics, thermosets and braze alloys may also be used for this layer 14. Additionally, multiple prestress layers 14 may be used to provide increased prestress. The adhesive is wet-coated or a thin film is melted onto one surface of the piezoelectric layer 12 and then bonded to it at an elevated temperature which is dependent on the adhesive being used and allows the material to undergo cure, drying, and/or melt flow. The layer of adhesive thus formed is typically twelve microns thick, but can range in thickness from a few microns to several mm. Bonding of the layers occurs at a high temperature, which depends upon the adhesive but is typically 200 - 350 ^{0}C, so that when the two-layer composite matrix cools to room temperature, the differential thermal compression rates of the layers

automatically impart the desired mechanical prestress into the layers, as shown in figure 2. If desired, the prestressing layer 14 of adhesive can be reinforced primarily to allow augmenting the level of prestress, but also for mechanical toughness and decreased hysteresis. To accomplish this, a thin layer of reinforcing material 16 is fused or bonded onto (figure 3), or into (figure 4), the prestressing layer 14. Examples of reinforcing materials include, but are not limited to, plastics, ceramics, metals and combinations of these materials such as aluminum sheet stock and carbon fibers. Bonding of the reinforcing material 16 can occur simultaneously with the bonding of the piezoelectric to the prestressing layer.

The adhesive layer allows the thin ceramic wafer to be cut to shape without chipping or fracturing using conventional cutting tools like scissors and pattern cutters allowing tailor-made shapes rather than molded shapes. This method enables techniques to be used which allow the pattern building of 3-dimensional objects from the consolidation of the 2-dimensional flat ceramic shapes. These layers can also offer additional environmental protection which allows these devices to be used in harsh conditions. If the adhesive layer used is a good dielectric, the chances of internal and external arcing due to the applied voltage are reduced.

In one embodiment, the piezoelectric device 10 according to the present invention contains two electrodes 18a and 18b. The electrodes 18a and 18b can be of the more conventional vacuum-deposited metal type, and can be applied onto the piezoelectric layer 12 prior to application of the prestressing layer 14. Alternatively, the electrodes can be a graphite or metal-plus-adhesive mixture such as silver epoxy, which is an excellent conductor. This alternate technique has the advantage that the conductive adhesive mixture can be coated onto the piezoelectric layer 12 and subsequently bonded to the piezoelectric layer 12, simultaneous with the bonding of the prestressing 14 and piezoelectric layers 12. Multiple or

patterned electrodes may also be used if necessary for the desired application.

The above teachings, may be combined to simplify the manufacture of piezoelectric devices. Complete devices can be produced by assembling separate layers of different materials, such as the appropriate mixtures of adhesively coated powdered piezoelectric material plus adhesive for the piezoelectric layer, conductive adhesive for the electrodes, and the adhesive by itself or as reinforcement for the prestressing layer, followed by a single high-temperature bonding operation as described in "Tough, Soluble, Aromatic, Thermoplastic Copolyimides", Serial No. 08/359,752, filed December 16, 1994.

Provisions should be made during the manufacturing process to ensure that the finished piezoelectric device has its prestressing layer in tension which places the piezoelectric material in the desired compression. The amount of prestress in the piezoelectric material can be tailored during manufacture in order to maximize the output motion and efficiency of the final device. The material layers may be formed on a curve-shaped mold.

A description typical of fabricating a prestressed device 10 by hand is provided here and shown in figure 5. A molding surface 20 is selected for the amount of curvature needed to provide the desired prestress. The prestress reinforcing layer 16 of aluminum foil is then placed on top of the molding surface 20. Next the adhesive prestress layer 14 made from a polyimide as described in "Tough, Soluble, Aromatic, Thermoplastic Copolyimides", Serial No. 08/359,752, filed December 16, 1994 is placed on top of the reinforcing layer 16. The electrode layer 18b of silver is vacuum deposited on the lower surface of the piezoelectric wafer 12 (this step is unnecessary if pre-electroded piezoelectric wafers are being used). The piezoelectric wafer 12 is placed on top of the adhesive prestress layer 14. Finally, an electrode layer 18a of silver is vacuum deposited on the upper surface of piezoelectric wafer 12, if necessary. A sheet of high temperature material 22, such as

Kapton® (DuPont), is placed over the stack and is sealed using high temperature bagging tape 24 to produce a vacuum bag. The assembly is placed into an oven and the air in the Kapton® bag 22 is evacuated through vacuum port 26. The oven is heated to 300°C to melt the adhesive and bond the assembly. Upon cooling, the assembly undergoes further prestressing, and the resulting piezoelectric device is removed from the vacuum bag and mold.

Although the ferroelectric wafers are typically poled as received from the vendor, they must be repoled following thermal treatment in the prestress process. The poling is done at an elevated temperature with a DC voltage sufficient to induce dipole orientation. After poling, the wafer is cooled to room temperature in the presence of the electric field to preserve the induced orientation. The DC field strength employed in the polarization is selected to obtain optimum polarization without exceeding the field at which dielectric breakdown occurs in the material at a given poling temperature.

The amount and type of input voltage per unit of deflection, motion, force and output voltage, current, or power conversion can be adjusted by varying the thickness and/or number of layers of the piezoelectric, the number of layers and/or thickness of the prestress layer, the prestress material, the piezoelectric composition and the curvature and shape of the molding surface. By varying the curvature of the mold, the prestress imparted to the finished piezoelectric device is varied. By varying the thickness or number of prestress material layers or by varying the material used, the output motion and mechanical force can also be varied. During processing, the piezoelectric and prestressing layers move with respect to each other and upon cooling bond together with additional prestress. This method of making devices has shown substantial increase of output motion of otherwise identical piezoelectric devices.

A cylindrical bender mode may be emphasized by prestressing in only one direction which can be done by bending the layers over a cylindrical

molding surface during the heating cycle. On cooling, the prestressing layer 14, being under the piezoelectric layer 12 has a tighter radius of curvature and prestresses more in one direction thus forming the bender. These cylindrical mode benders are typically shapes other than circular as shown in figure 6.

A number of individual, polygon-shaped piezoelectric devices 28 can be grouped into a large-area mosaic by joining their appropriate edges as shown in figure 7. One useful method for edge attachment is the use of a single reinforcing layer that covers the entire mosaic.

Certain applications may require more mechanical output force than can be provided by a single device 10. Two or more devices 10 can then be used in an efficient tandem arrangement by uniting their dome-like shapes in a 'stacked-spoons' configuration. Figure 8 shows three devices in this stacked configuration. To allow unimpeded bending of the individual devices during operation the devices can be bonded to each other using a compliant layer 30, such as an elastomer, i.e. silicone rubber, which allows one layer to move relative to the other. In such an actuator stack, the individual devices 10 remain electrically isolated from each other; one or more of the devices 10 can act as a motion feedback sensor.

When made using a matrix composite fabrication method shown in "Tough, Soluble, Aromatic, Thermoplastic Copolyimides", Serial No. 08/359,752, filed December 16, 1994, large flexible sheets may be produced for use in low-frequency actuator applications (i.e. noise canceling devices or loud speakers). This can be accomplished by using large flat molds for consolidation or a continuous roll process. Molded parts can be bonded together by heating them to soften and/or cure the binder adhesive while pressing them together.

Ferroelectric devices made from the present method can be used in pumps, valves, brakes, motors, sensors, actuators, optics, acoustic transducers, and active structures.

Many improvements, modifications, and additions will be apparent to the skilled artisan without departing from the spirit and scope of the present invention as described herein and defined in the following claims.

What is claimed is:

Claims:

1. A ferroelectric device, comprising:

a prestress layer placed on a mold;

a ferroelectric layer placed on the prestress layer, such that a layered structure is created;

means for heating the prestress and ferroelectric layers; and

means for cooling the prestress and ferroelectric layers such that the heating and cooling means induce a prestress into the layered structure.

2. The method of claim 1, wherein the prestress layer includes reinforcing material.

3. The method of claim 1 wherein the ferroelectric layer includes surface electrodes.

4. The method of claim 1, further comprising:

an electrode layer placed between the prestress layer and the ferroelectric layer; and

an electrode layer placed on top of the ferroelectric layer.

5. The method of claim 1 wherein the prestress layer is an adhesive.

6. The method of claim 1 wherein the ferroelectric layer is a piezoelectric material.

7. The method of claim 1 wherein the ferroelectric layer is a piezostrictive material.

8. The method of claim 1 wherein the ferroelectric layer is formed from a composite.

THIN LAYER COMPOSITE UNIMORPH FERROELECTRIC DRIVER AND SENSOR

Abstract of the Disclosure

A method for forming ferroelectric wafers is provided. A prestress layer is placed on the desired mold. A ferroelectric wafer is placed on top of the prestress layer. The layers are heated and then cooled, causing the ferroelectric wafer to become prestressed. The prestress layer may include reinforcing material and the ferroelectric wafer may include electrodes or electrode layers may be placed on either side of the ferroelectric layer. Wafers produced using this method have greatly improved output motion.

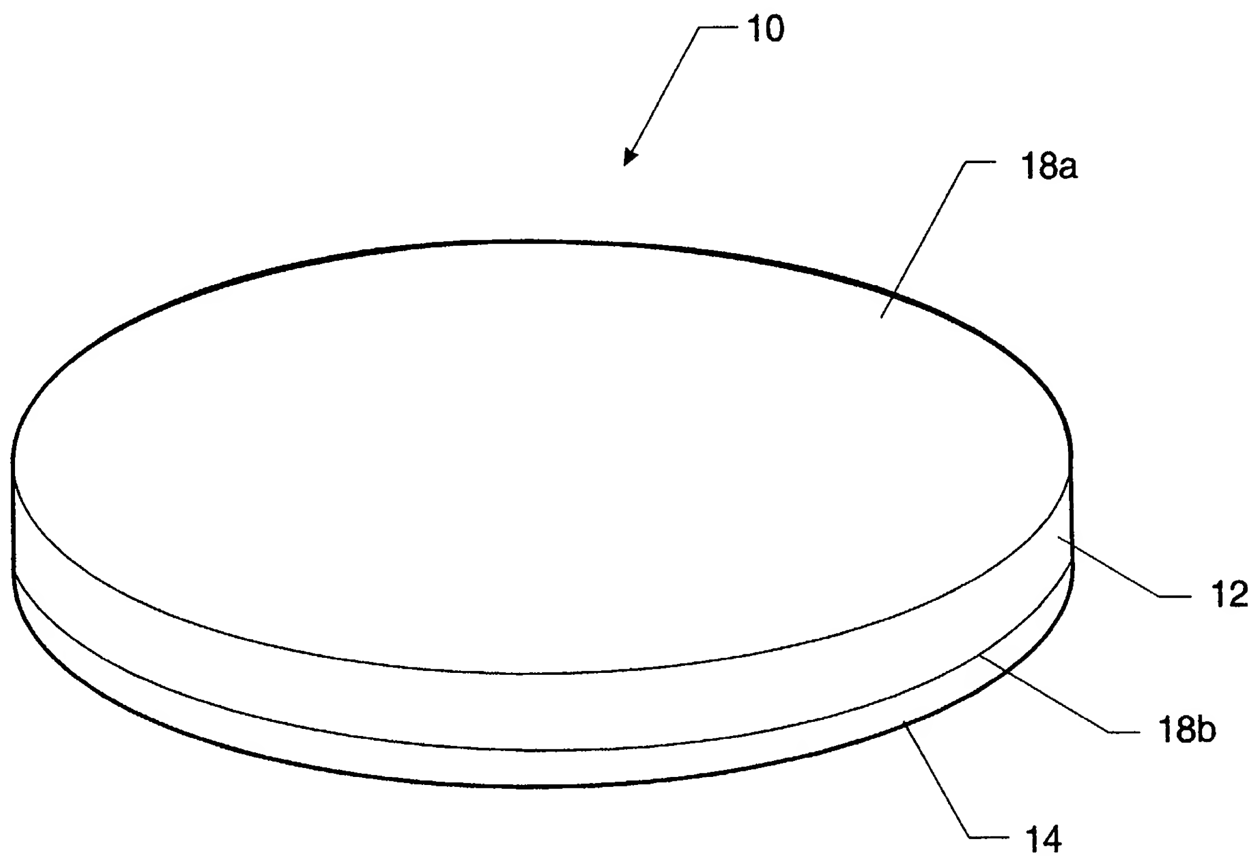

FIG. 1

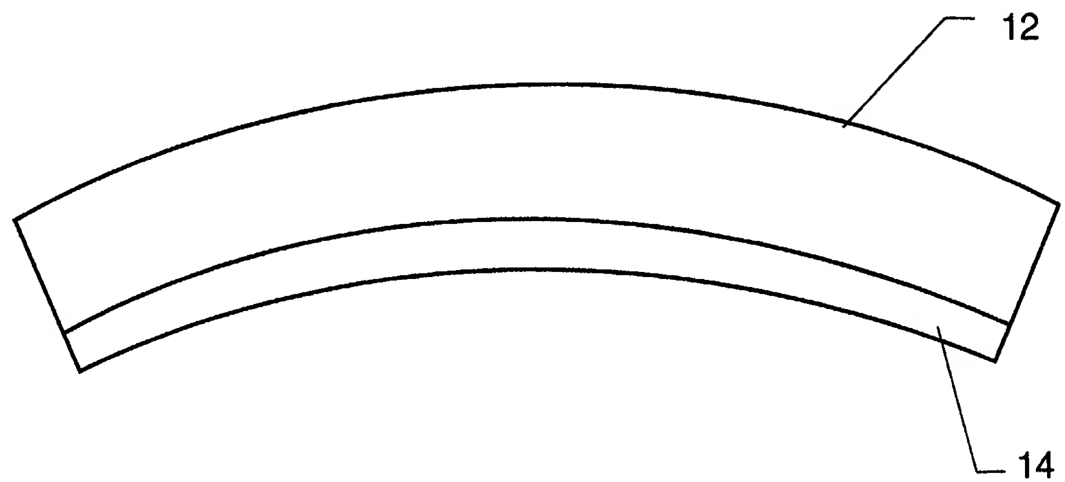

FIG. 2

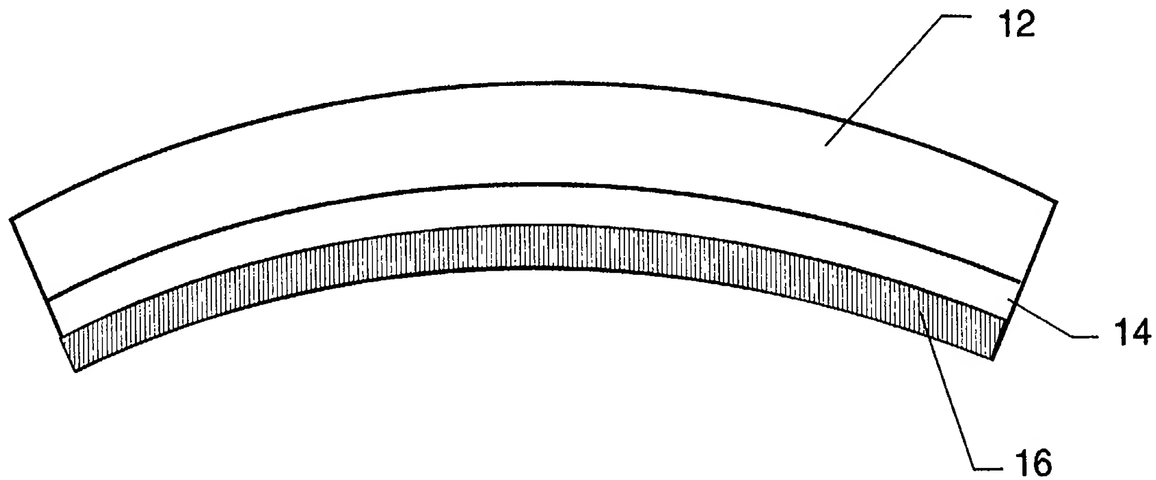

FIG. 3

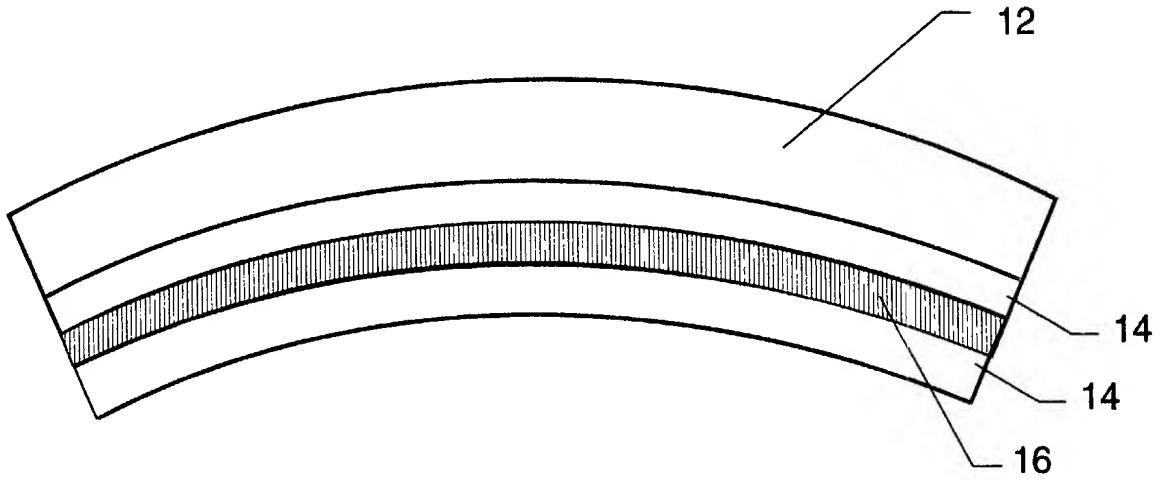

FIG. 4

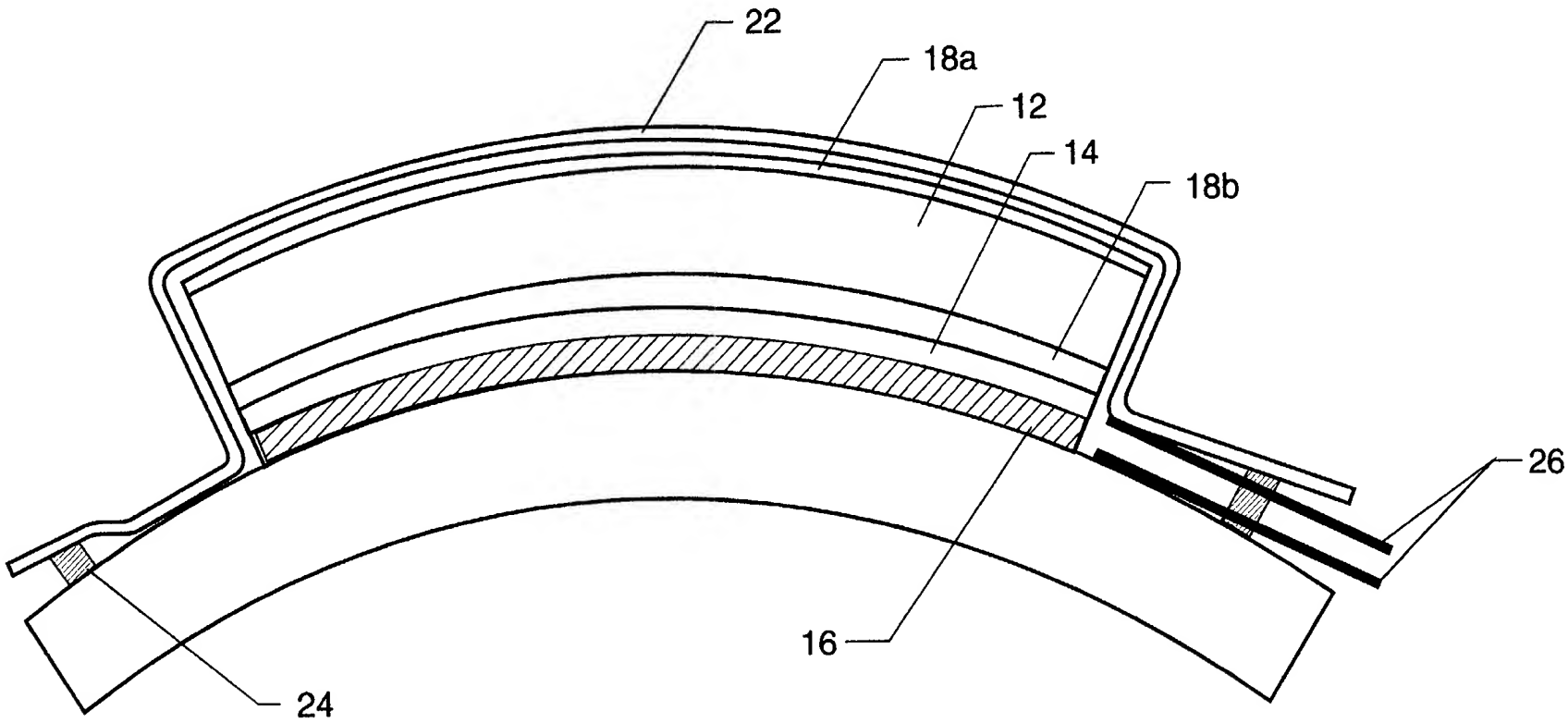

FIG. 5

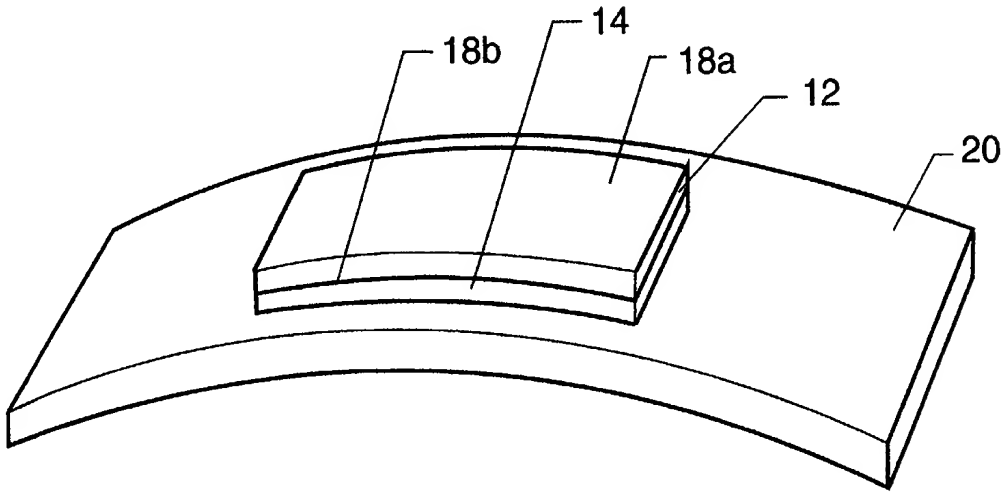

FIG. 6

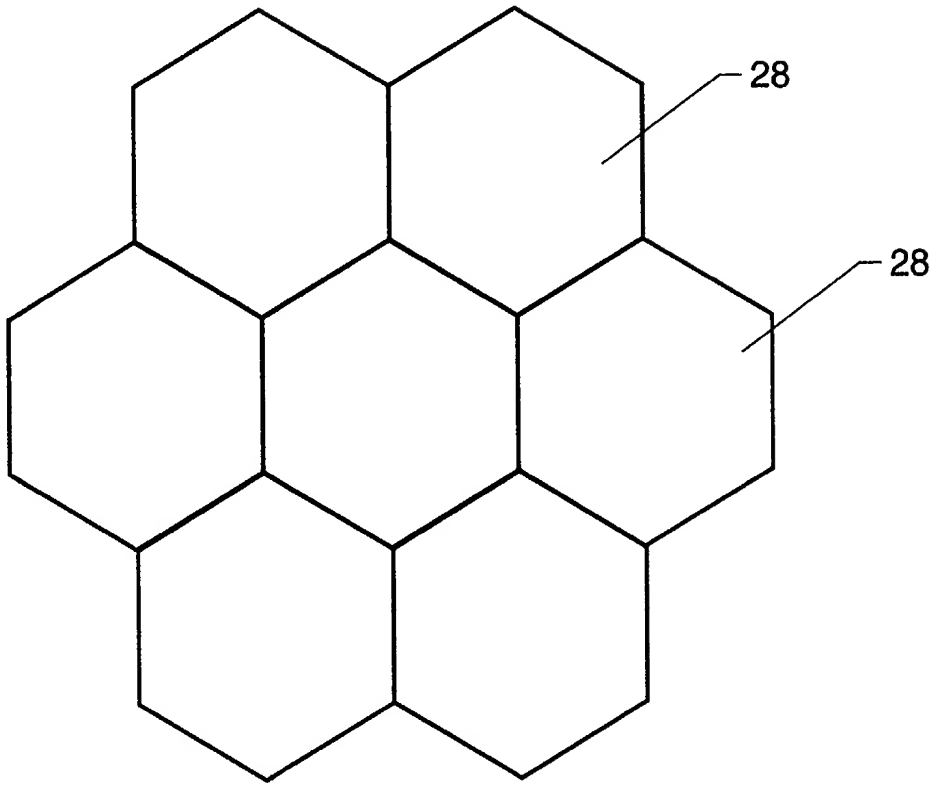

FIG.7

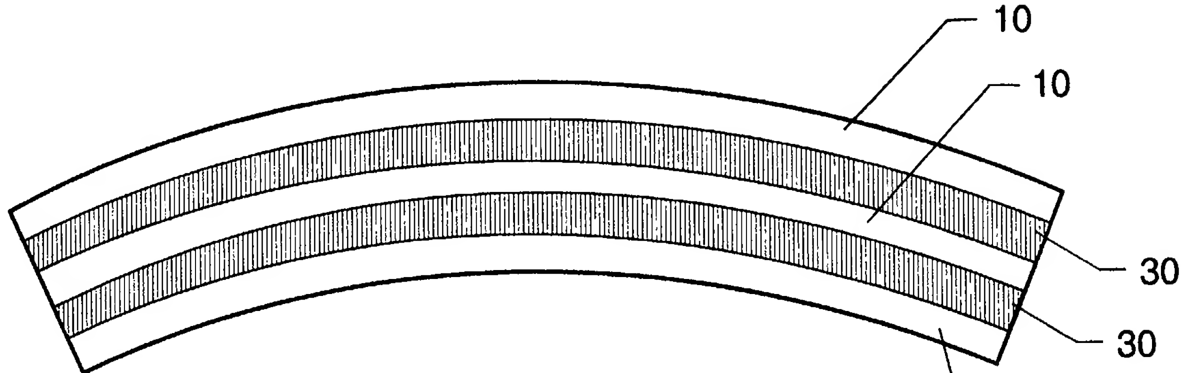

FIG. 8

NASA Case No.: LAR 15348-2

NASA

National Aeronautics and Space Administration

DECLARATION, POWER OF ATTORNEY AND PETITION ORIGINAL APPLICATION

As a below named inventor, I hereby declare that: my residence, post office address and citizenship, are stated below next to my name, I believe I am the original, first and sole inventor (If only one name Is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled THIN-LAYER COMPOSITE-UNIMORPH FERROELECTRIC DRIVER AND SENSOR , the specification of which ✓ is attached hereto, _ was filed on (Date) _____ as Application Serial No. _____ and was amended on (Date)_____.

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Patent and Trademark Office all information which is known to me to be material to patentability as defined in 37 CFR §1.56.

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application: **08/416,59** Serial No.), **April 4, 1995** (Filing Date) ,the status of which is

_ patented, ✓ pending, _ abandoned.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(e) of any United States Provisional applications listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE
_____ / _____	_____
_____ / _____	_____,

the status of which is

_ patented, _ pending, _ abandoned.

POWER OF ATTORNEY: I hereby appoint the following attorney(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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Further, as a named inventor I certify that the Government of the United States of America, as represented by the Administrator of the National Aeronautics and Space Administration, has ✓ an assignment in, or _ license to the invention set forth in this application and has the irrevocable right to practice this application and to receive the patent.

Wherefore, I pray that Letters Patent be granted to me for this invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification, claims, power of attorney and this petition.

I hereby declare that all statements made herein of my own knowledge are true and that - statements made on information and belief are believed to be true; and further that these, statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S C §1001; and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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SIGNATURE	Robert L Fox		DATE 1/23/97

Further, as a named inventor I certify that the Government of the United States of America, as represented by the Administrator of the National Aeronautics and Space Administration, has ✓ an assignment in, or _ license to the invention set forth in this application and has the irrevocable right to practice this application and to receive the patent.

Wherefore, I pray that Letters Patent be granted to me for this invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification, claims, power of attorney and this petition.

I hereby declare that all statements made herein of my own knowledge are true and that - statements made on information and belief are believed to be true, and further that these, statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001; and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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